

# **AGILE** AIRCRAFT 3<sup>RD</sup> GENERATION MDO FOR INNOVATIVE COLLABORATION OF HETEROGENEOUS TEAMS OF EXPERTS

## AGILE

### THE NEXT GENERATION OF COLLABORATIVE MDO

ICAS CASIMIRO MONTENEGRO FILHO LECTURE FOR INNOVATION IN AERONAUTICS

AWARD FOR INNOVATION IN AERONAUTICS

11<sup>TH</sup> SEPTEMBER 2018



DLR

*Björn Nagel, Pier Davide Ciampa*

Deutsches Zentrum  
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German Aerospace Center

Institute of System Architectures in Aeronautics  
Integrated Aircraft Design  
HAMBURG



This project has received funding from the European Union's Horizon 2020 research and innovation framework programme under grant agreement No 636202



# Innovation in Aeronautics

DEMAND



Mobility



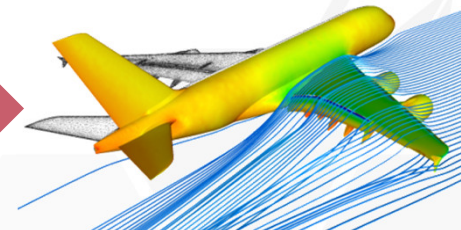
Environment



Economy



Propulsion



Aerodynamics



Manufacturing

TECHNOLOGIES

**AGILE - next generation of collaborative MDO**

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# Towards the next Generation MDO

## 3rd Gen. MDO: a system of distributed competences

source: p.d. ciampa, b.nagel, "Towards the 3rd generation MDO collaboration Environment," in 30th Congress of the International Council of the Aeronautical Sciences, Daejeon, 2016

### 1) first (~80)

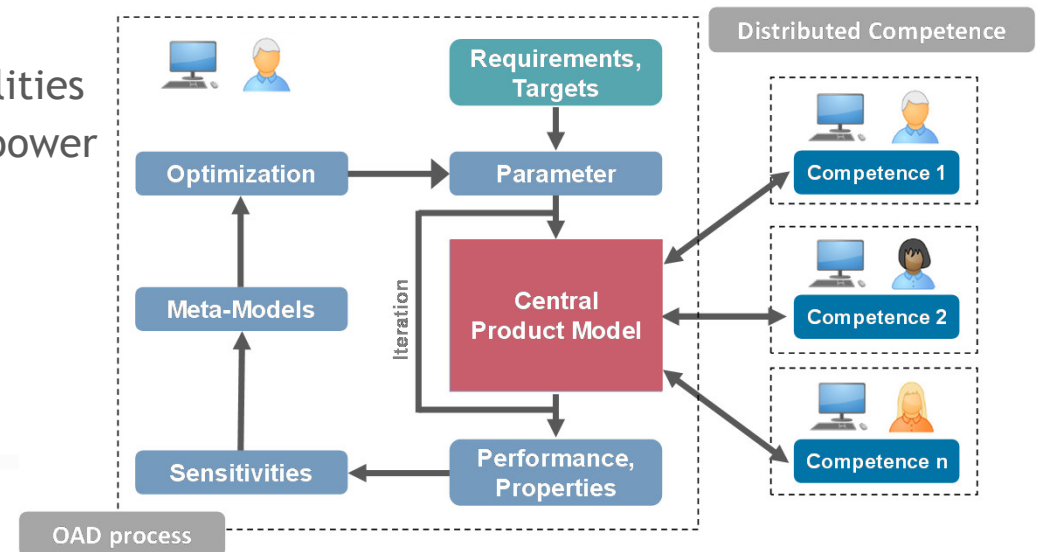
- Disciplinary Simulation and optimization capabilities
- Optimization Strategies for low computational power

### 2) second (~00-today)

- HPC capabilities and simulation distribution
- Automation of analysis capabilities

### 3) third (next gen)

- Integration of expertise in the collaborative optimization
- Knowledge formalization of process and disciplinary domains



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*„Having Tools“ is not „Having Skills“*





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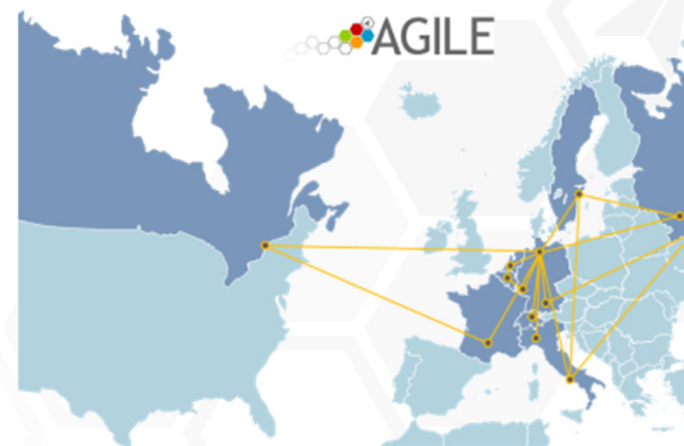


European  
Commission

Innovation  
and Networks  
Executive Agency

**EU funded H2020 project: 06/2015-11/2018**

- 19 International Partners (EU, Russia, Canada)
- ~ 9M EUR, ~ 120 MM
- Coordinated by DLR in Hamburg
- EU project **dedicated to next generation MDO processes**



<http://agile-project.eu>

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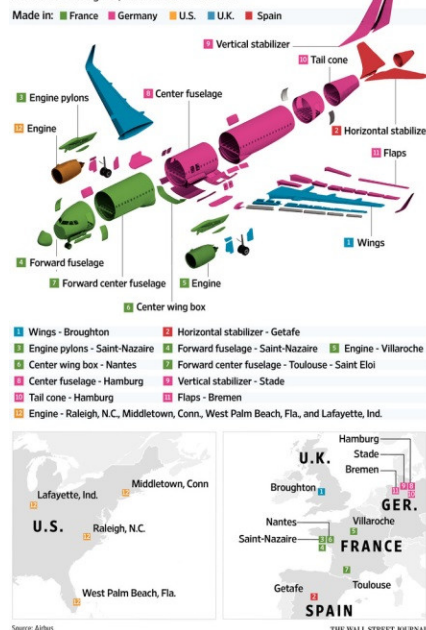
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# Speed of Innovation in Aeronautics

- Aircraft Product Development → large number of **parts** and design **sub-processes**
- Cross-organizational → **distributed** and **heterogeneous** knowledge and expertise
- Much more constraints → higher level **integration** of design aspects

## Globally Sourced

Airbus planes are built mostly in Europe but rely on parts, such as some engines, from all over the world.



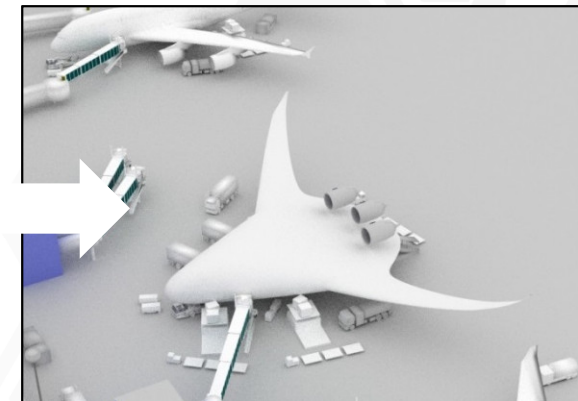
## Can we accelerate aircraft development via MDO?

Today (~10 years from TLAR to flight)



Number of parts: 6 millions  
Design changes per year: 150 000

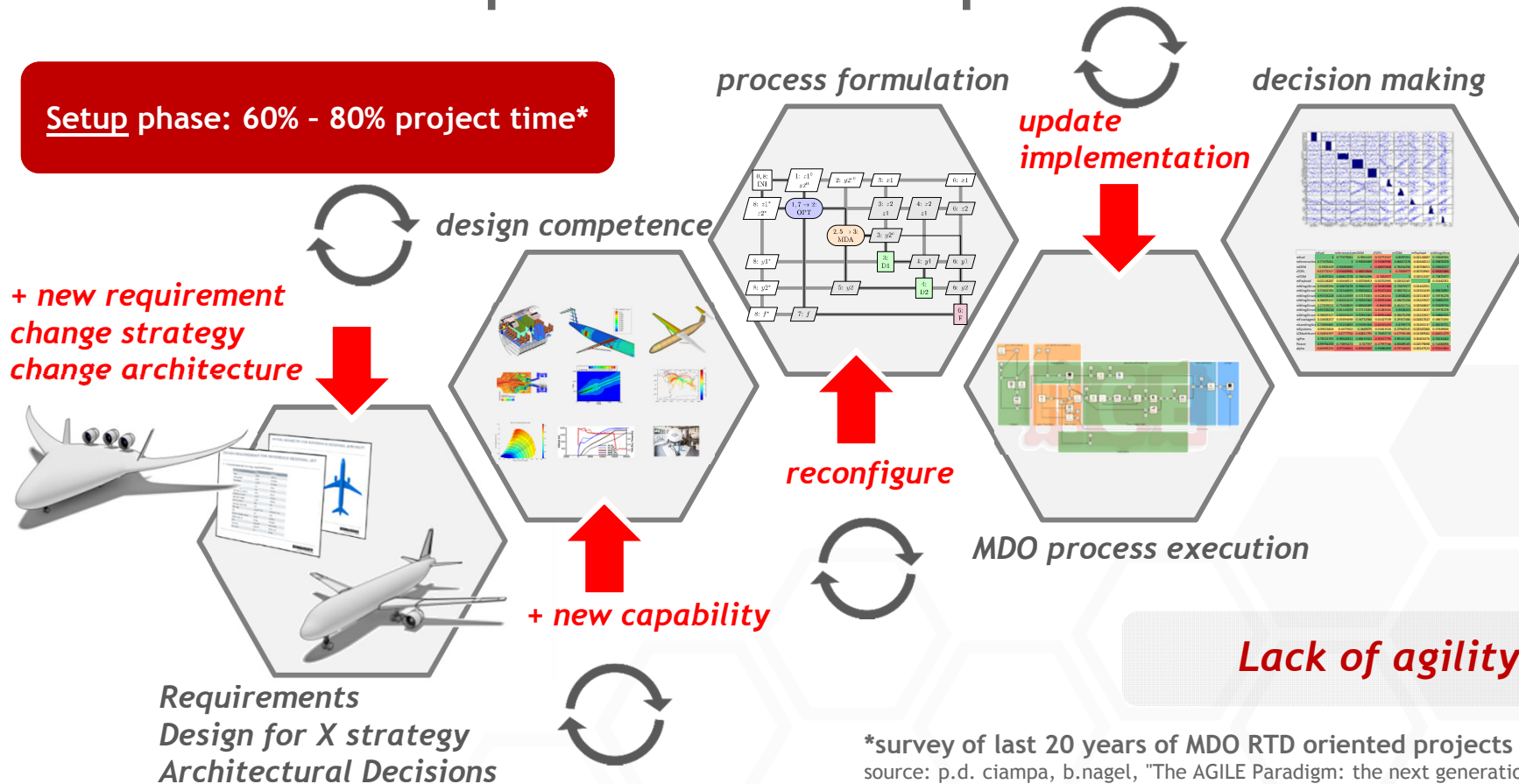
Tomorrow ?



source: dlr.de

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# Aircraft Development and MDO process



\*survey of last 20 years of MDO RTD oriented projects [3-5 yrs],  
source: p.d. ciampa, b.nagel, "The AGILE Paradigm: the next generation of collaborative MDO"  
AIAA 2017-4137



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# AGILE Ambition

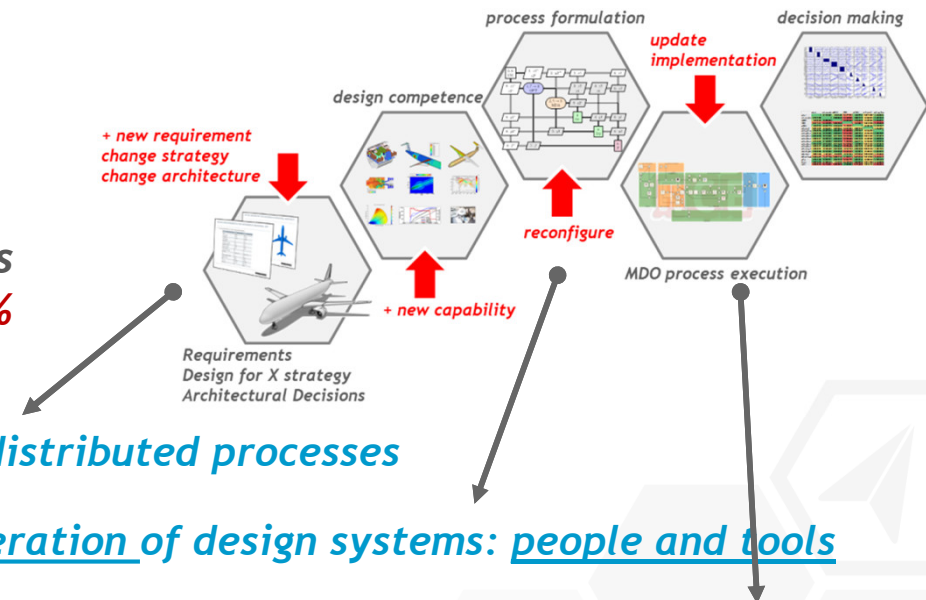
## Objectives:

- Realize the **next generation of MDO** processes
- Reducing aircraft **MDO development time 40%**
- Enabling **Collaborative** Aircraft Design

Accelerate the setup of large scale collaborative distributed processes

Support collaborative operation of design systems: people and tools

Efficient collaborative Optimization techniques



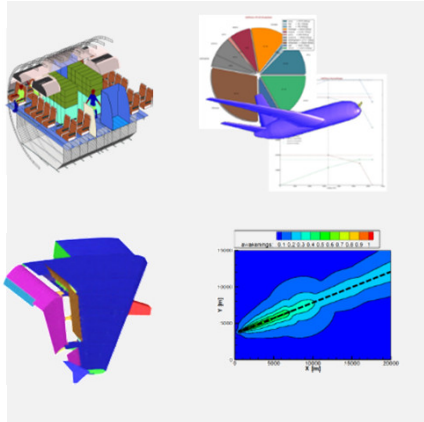
## AGILE Configurations



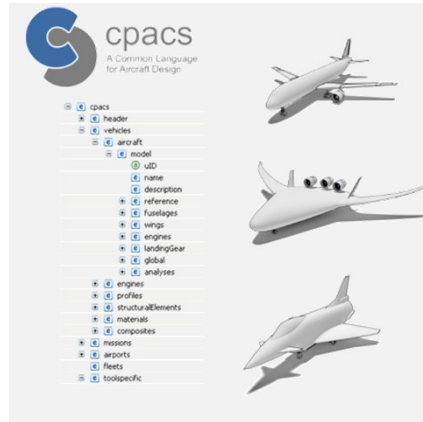
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# What do we need for the next generation MDO?

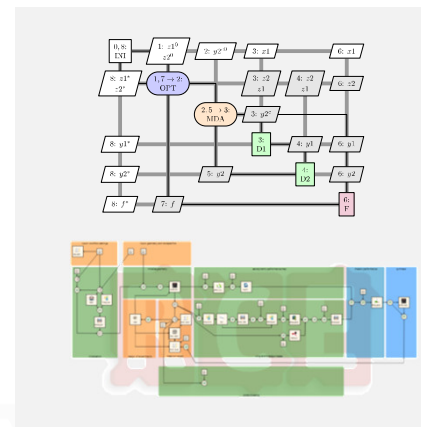
## design competences



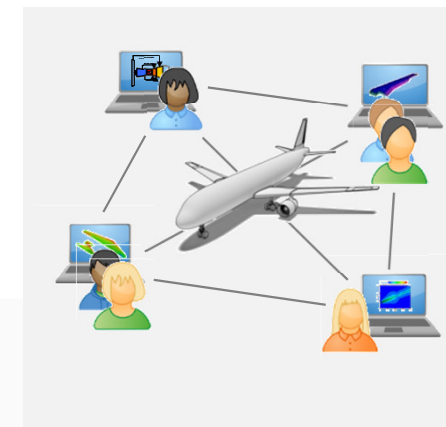
## common languages



## design process orchestration



## knowledge integration



**AGILE Paradigm: “a blueprint for collaborative MDO deployment”**

source: p.d. ciampa, b.nagel, “AGILE the Next Generation of Collaborative MDO: Achievements and Open Challenges” AIAA 2018-3249



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# AGILE Paradigm - *Participative Roles*

source: p.d. ciampa, b.nagel, "AGILE the Next Generation of Collaborative MDO: Achievements and Open Challenges" AIAA 2018-3249

- Define the design task and product metrics
- Formalize the design phases and process(-es)



**Architect**



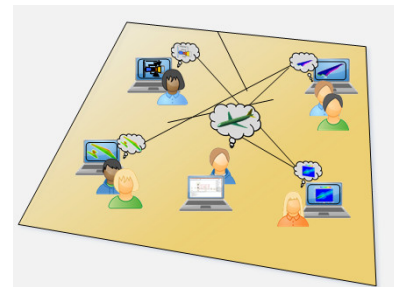
**Integrator**



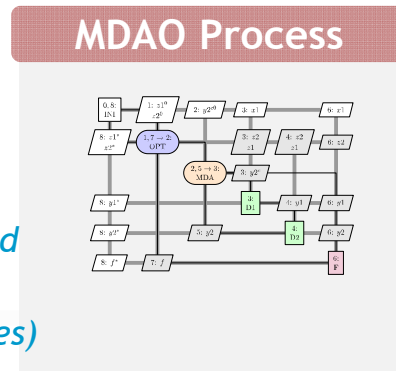
- Formulate the integration and optimization strategy
- Formalize the MDO process(-es)



**Design Task**



**Collaboration**



**MDAO Process**



**Design Competence**

- Enable the collaborative operation of the system
- Formalize the collaborative process(-es)



**Collaborative Eng.**



**Specialist**



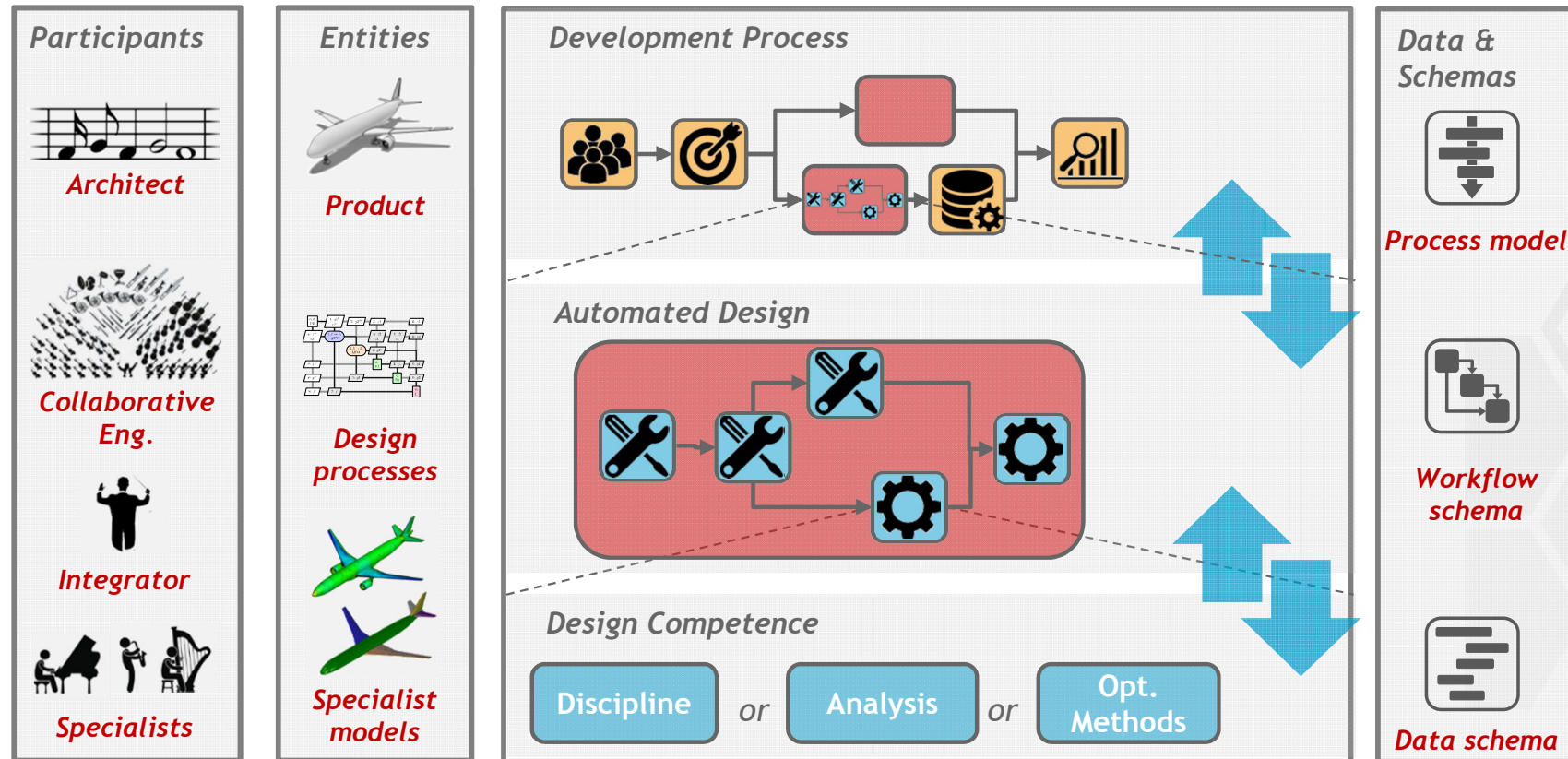
- Provide Design Capabilities
- Formalize the disciplinary knowledge



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# AGILE Paradigm - *Knowledge Layers*

source: p.d. ciampa, b.nagel, "AGILE the Next Generation of Collaborative MDO: Achievements and Open Challenges" AIAA 2018-3249

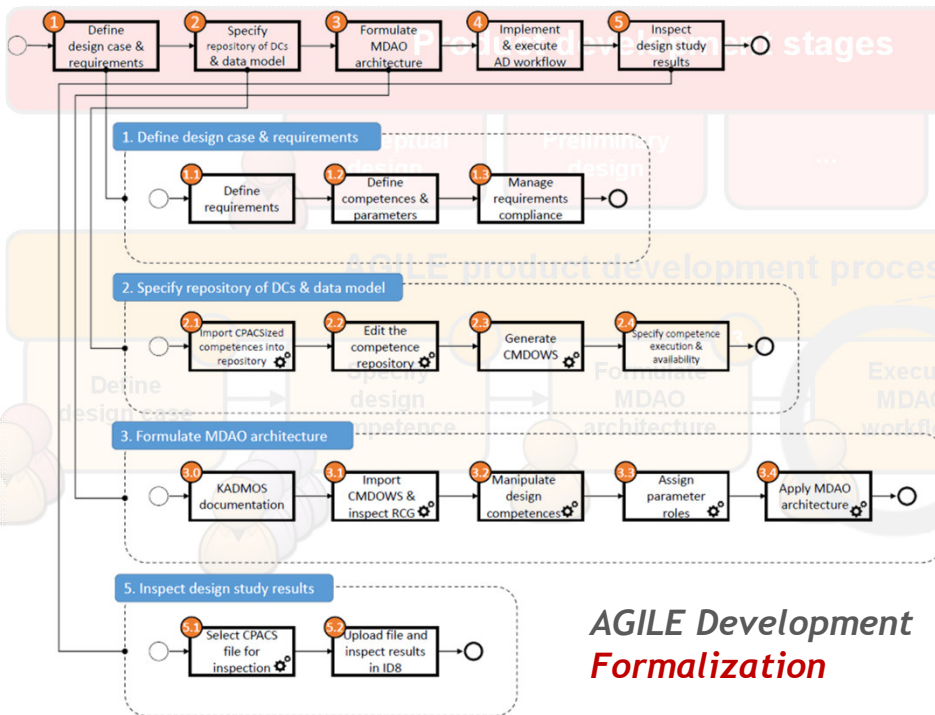


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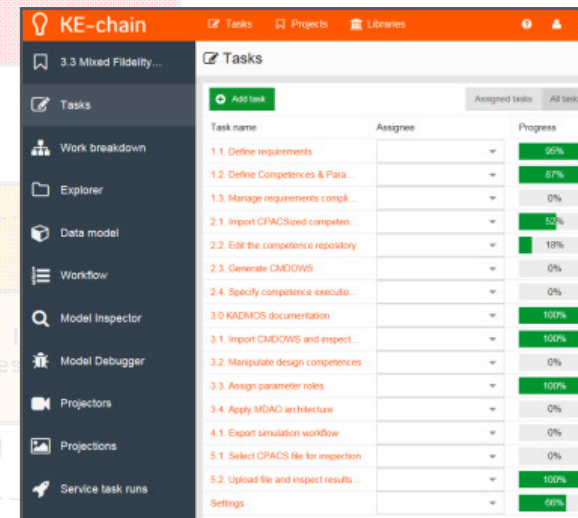
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# AGILE Paradigm - *Development phases*

- Requirements Modeling and Management
- Formalization of Product Development Process (PDP)



**AGILE Development  
Formalization**



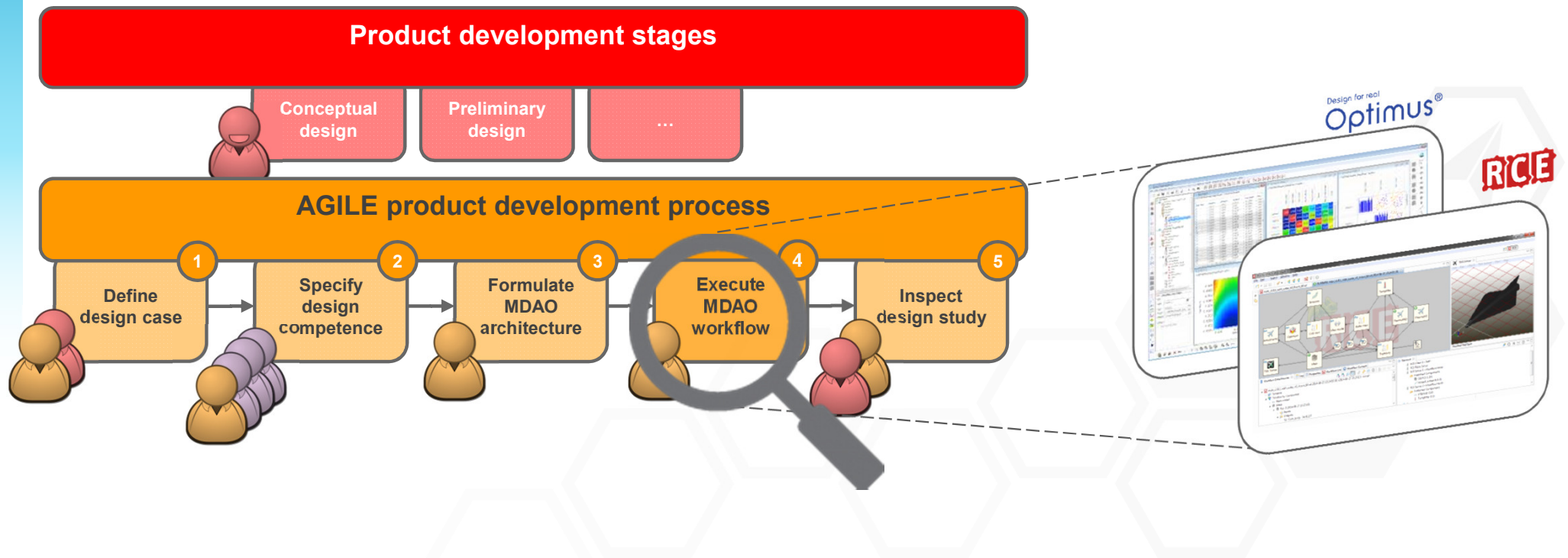
**AGILE Development  
Implementation**



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# AGILE Paradigm - *Development phases*

- Requirements Modeling and Management
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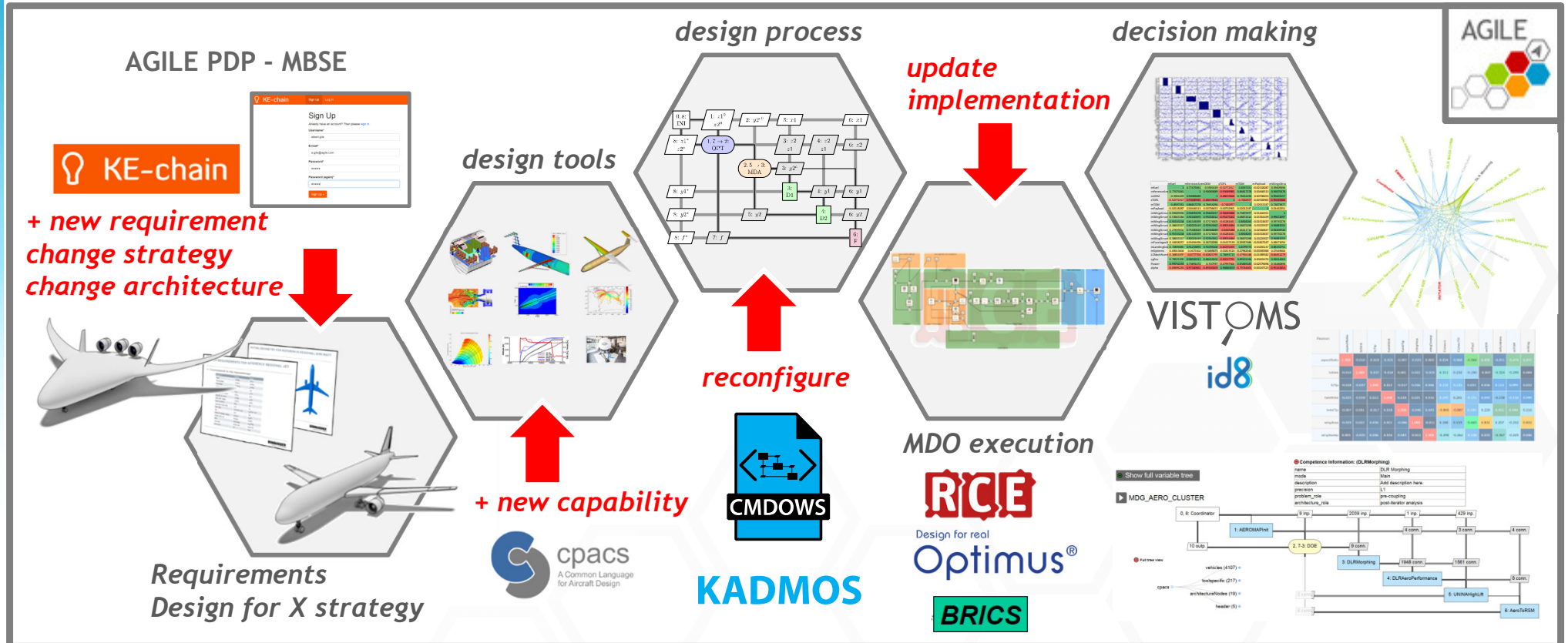


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# AGILE Paradigm - *Model Based Framework*

AGILE Framework



source: p.d. ciampa, b.nagel, "AGILE the Next Generation of Collaborative MDO: Achievements and Open Challenges" AIAA 2018-3249



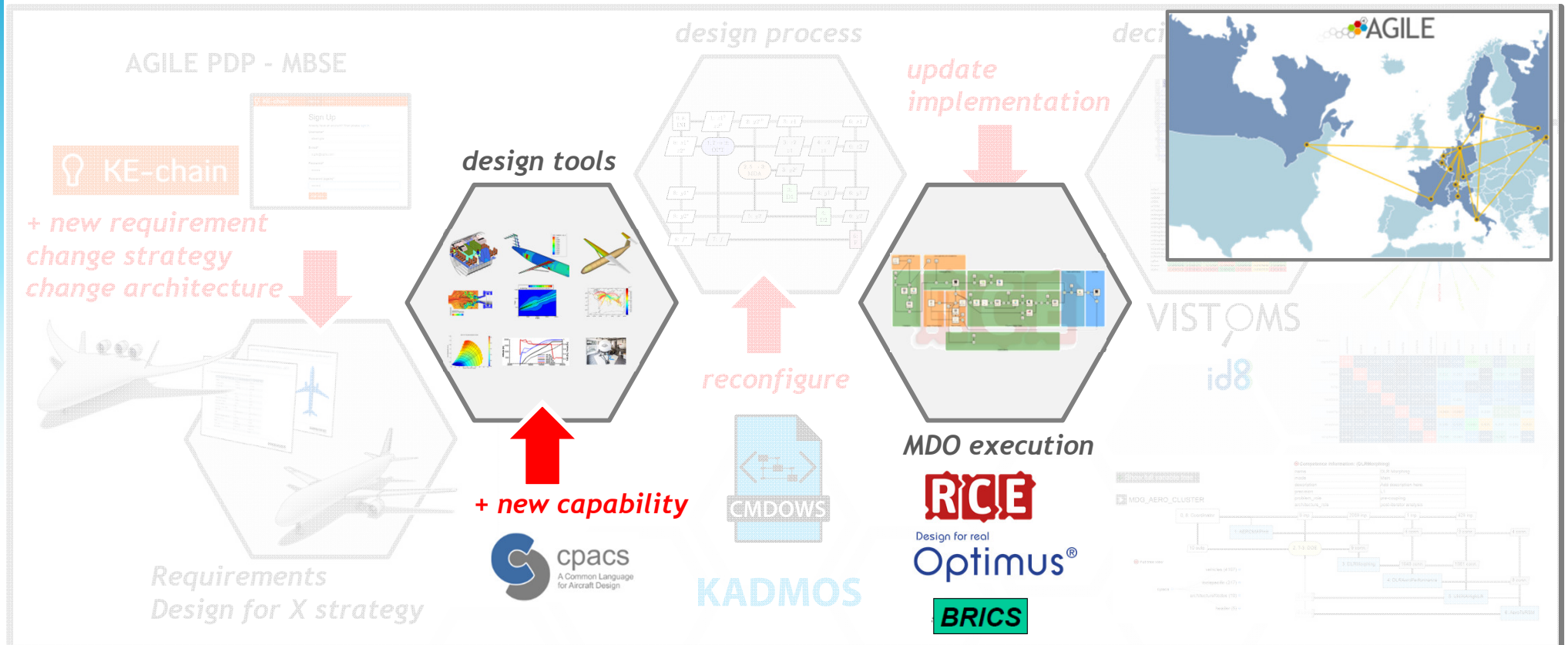
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# AGILE Framework - *Cross-organizational*

AGILE Framework



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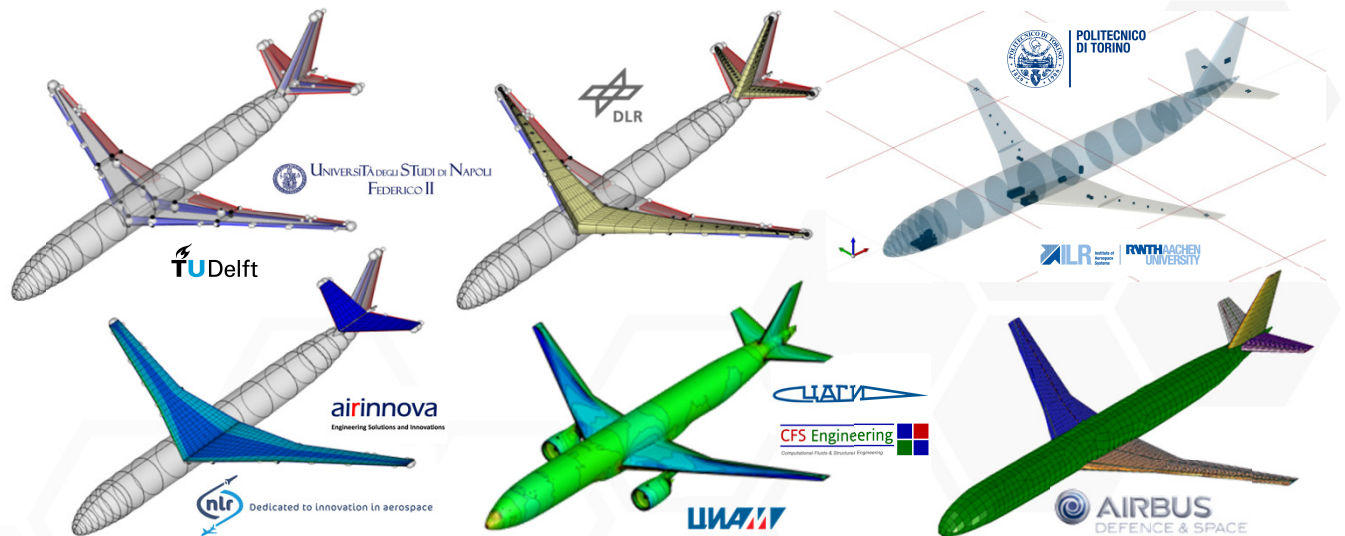
# AGILE - Collaboration challenges

- Knowledge Modeling and Collaboration
- Design Competence wrapping process (right syntax) → Speaking the same “language”
- Disciplinary interpretation process (right semantic) → Meaning the same “Concepts”
- Design Competences Integration → Accessing and providing “tools and knowledge”

AGILE reference aircraft CPACS



<https://cpacs.de>



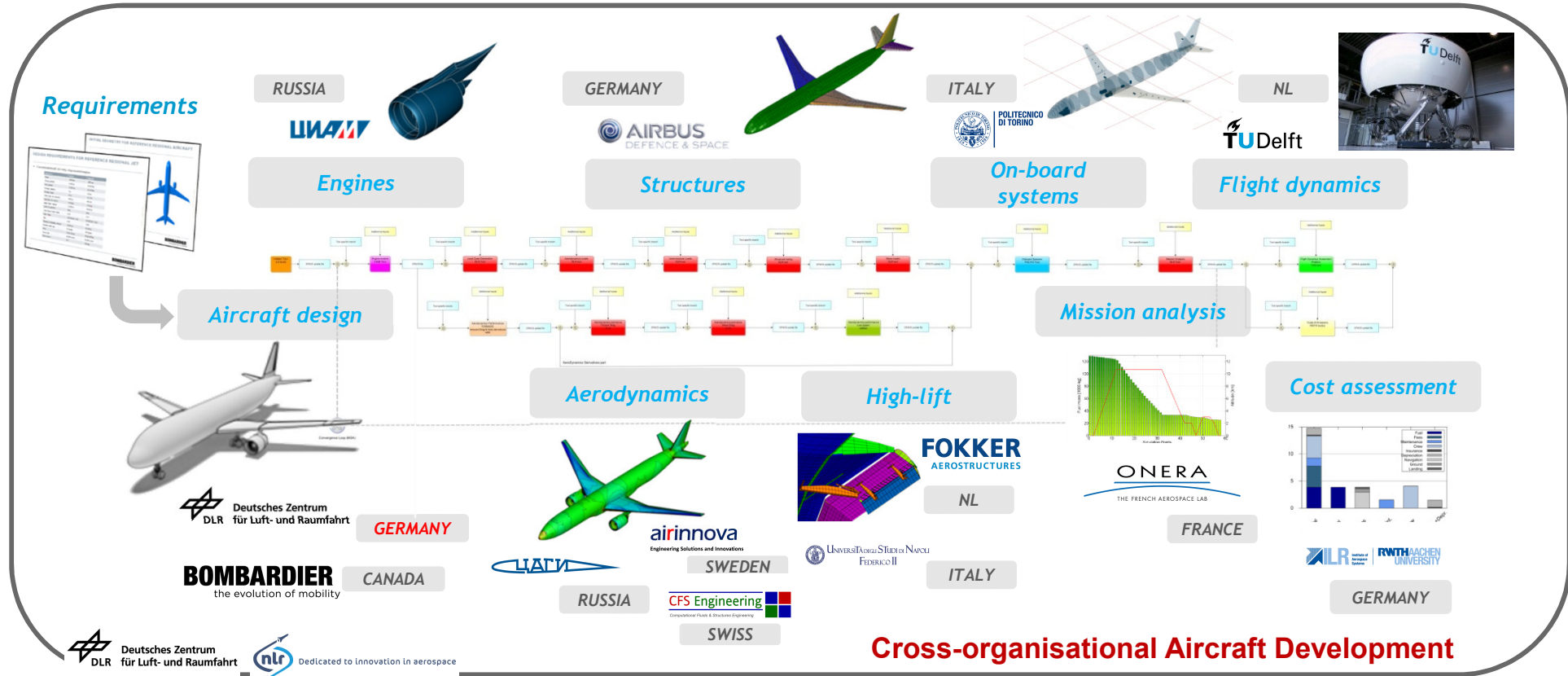
AGILE reference aircraft disciplinary models by Partners from *a single source*

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# AGILE Phase 1 - *from TLAR to “flying” in 15 months*



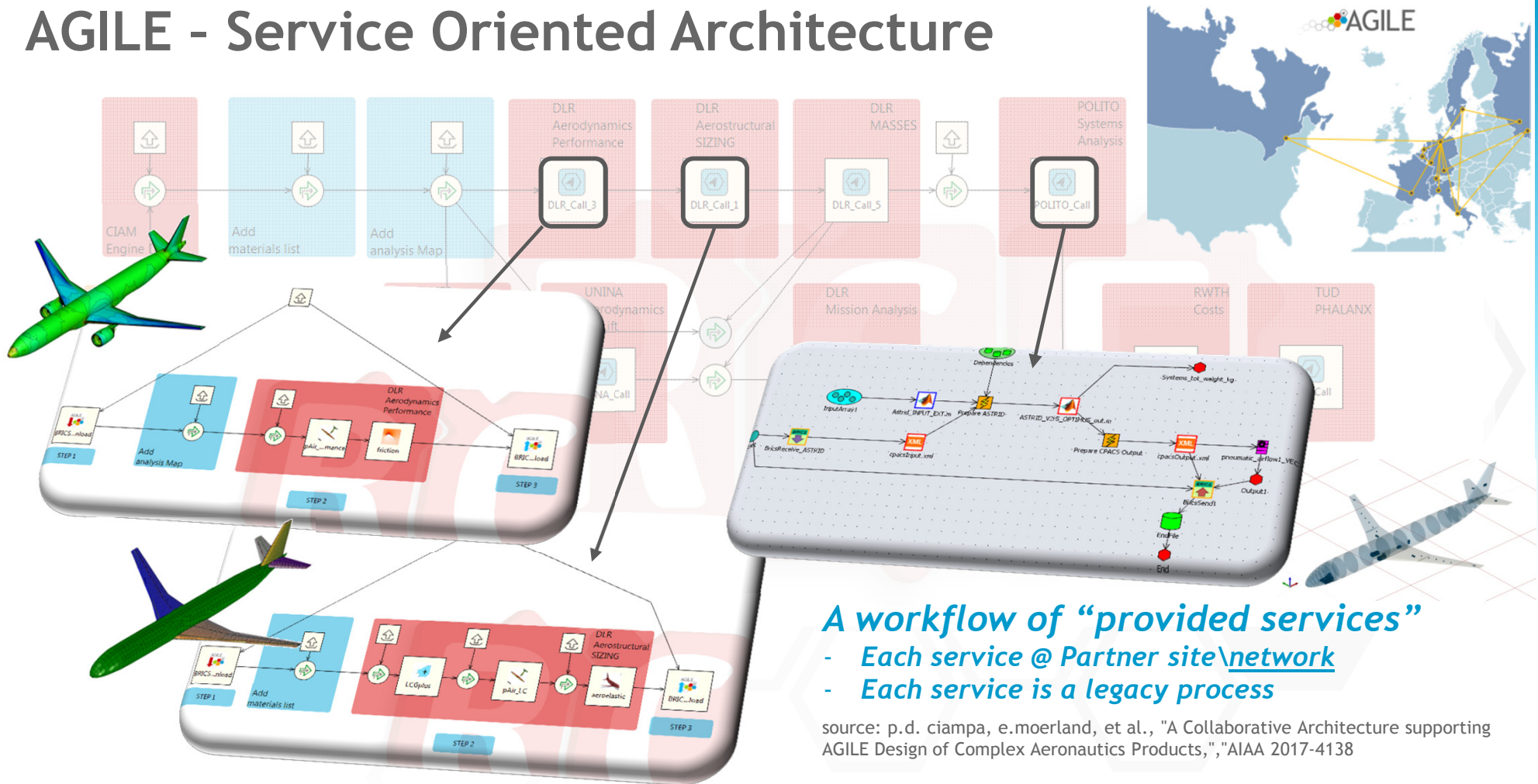
source: p.d. ciampa, b.nagel, "The AGILE Paradigm: the next generation of collaborative MDO," AIAA 2017-4137

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# AGILE - Service Oriented Architecture



## A workflow of “provided services”

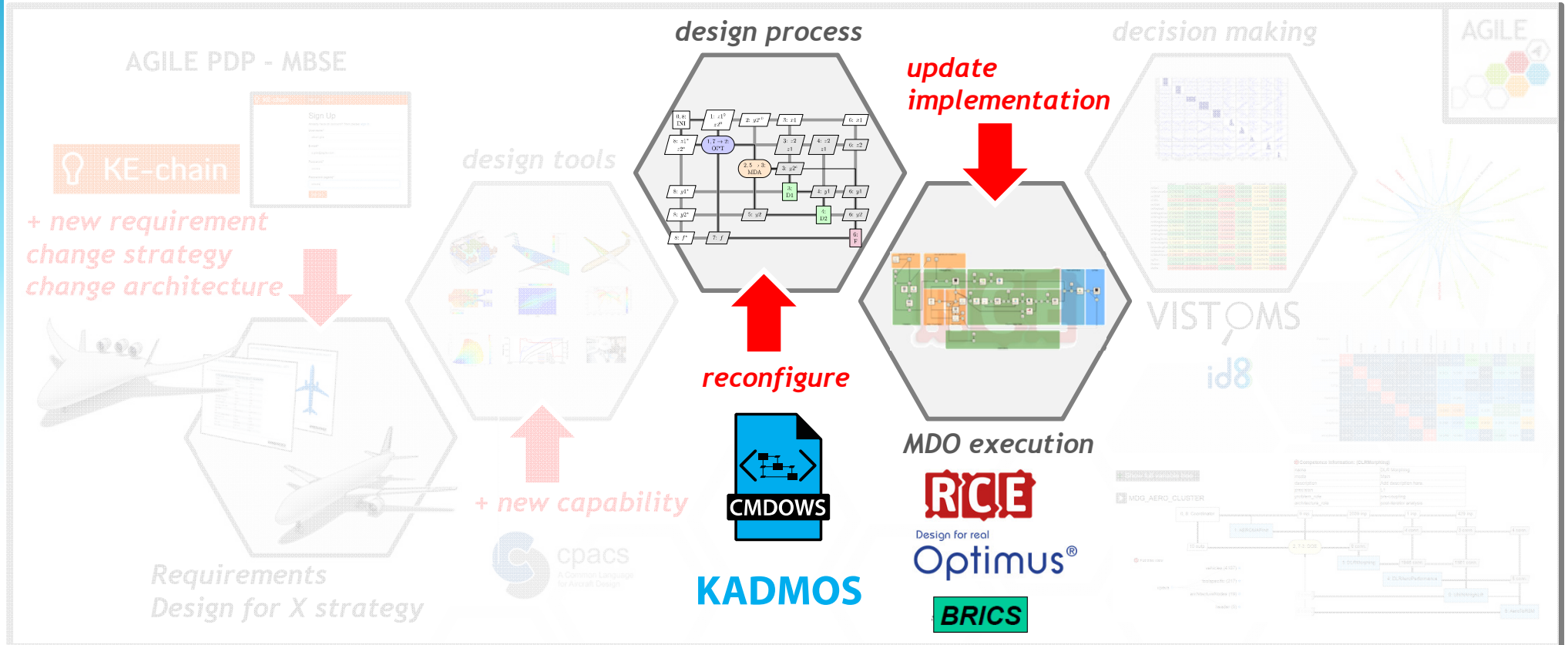
- Each service @ Partner site\network
- Each service is a legacy process

source: p.d. ciampa, e.moerland, et al., "A Collaborative Architecture supporting AGILE Design of Complex Aeronautics Products," "AIAA 2017-4138



# AGILE Framework - *Automation & Optimization*

AGILE Framework

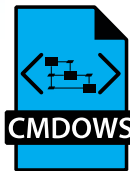


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# Design Process Automation



**CMDOWS**

**Common MDO Workflow Schema**

- ④ MDO process description developed in AGILE project.
- ④ Formalizes the MDO processes in a "neutral format"
- ④ Enable to share MDO processes between MDO frameworks
- ④ Provides the MDO process model which can be manipulated

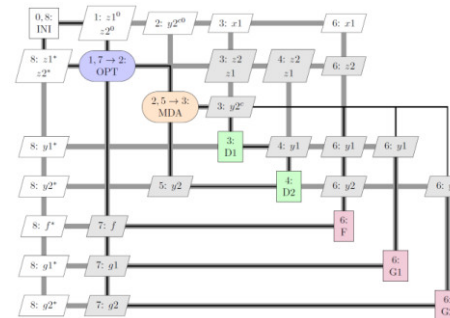
[cmdows-repo.agile-project.eu](http://cmdows-repo.agile-project.eu)



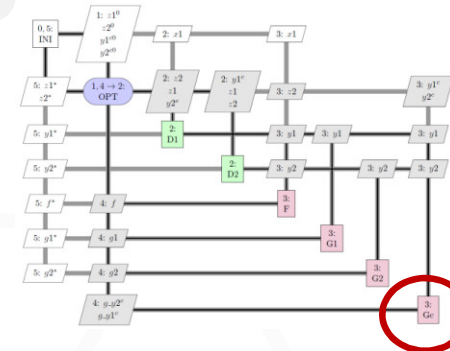
**MDF**

**MDO Architecture?**

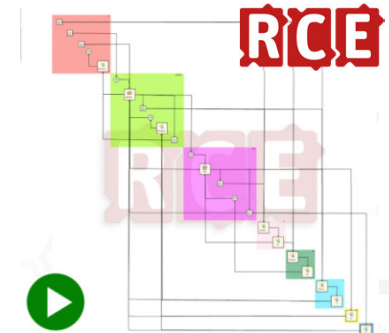
**IDF**



**Stored as MDO Model**



**Integration Framework?**



**Automated Translation**

**Recent work**

**openMDAO**

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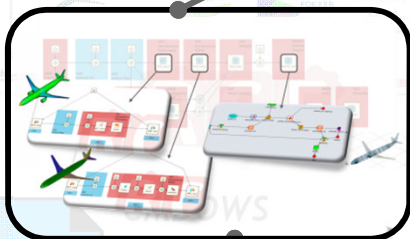
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# Design Process Automation

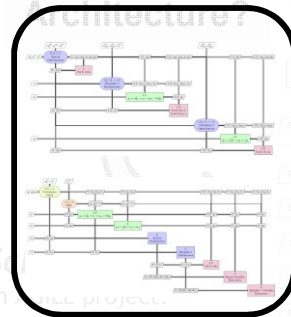
## Flexibility Achieved:

- Generation of Design Process Architectures Fully Automated
- Assessment of different design strategies

Design Process



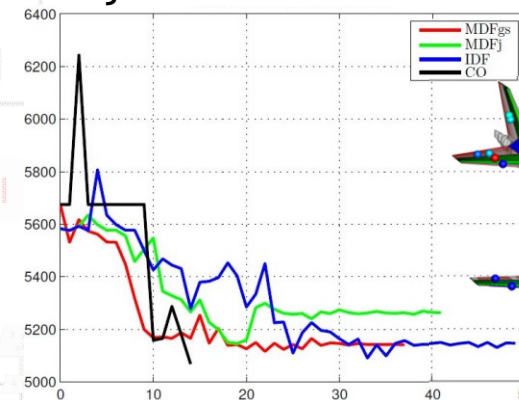
Monolithic → computation performance



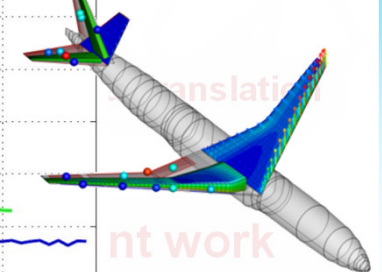
Distributed → for Organization structured in disciplinary departments

source: f. torrigiani, p.d. ciampa, "MDO Architectures Comparison on Analytical Test Case and Aerostructural Aircraft System Design Problem", 6<sup>th</sup> CEAS Conference, 2017

## Objective Function



Optimization Iterations

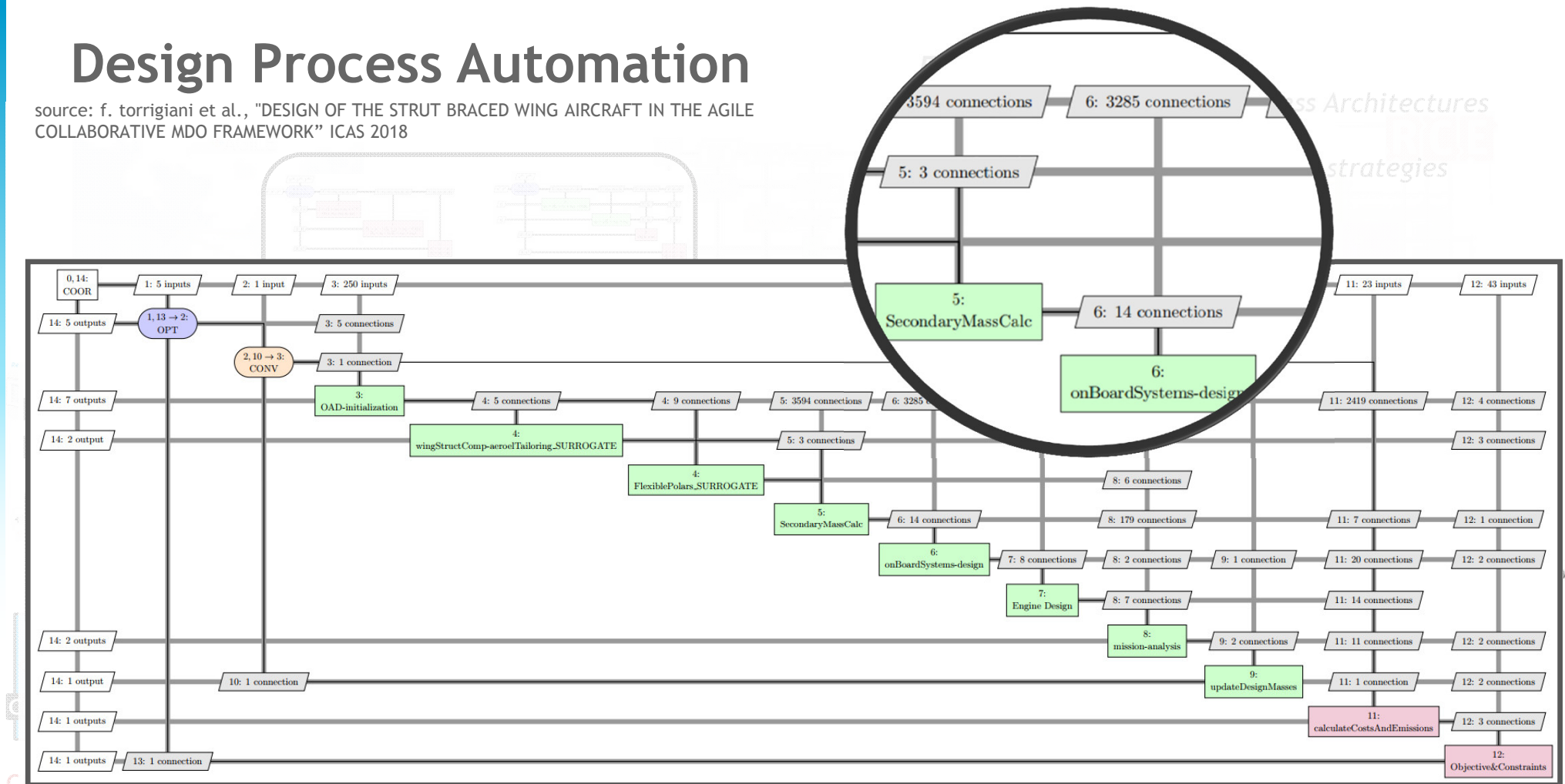


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# Design Process Automation

source: f. torrigiani et al., "DESIGN OF THE STRUT BRACED WING AIRCRAFT IN THE AGILE COLLABORATIVE MDO FRAMEWORK" ICAS 2018



AGILE Strut Braced Wing

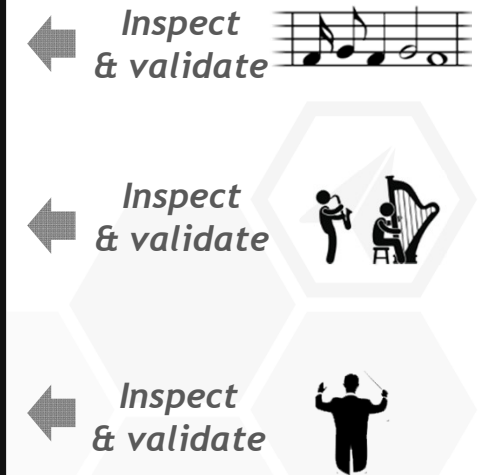
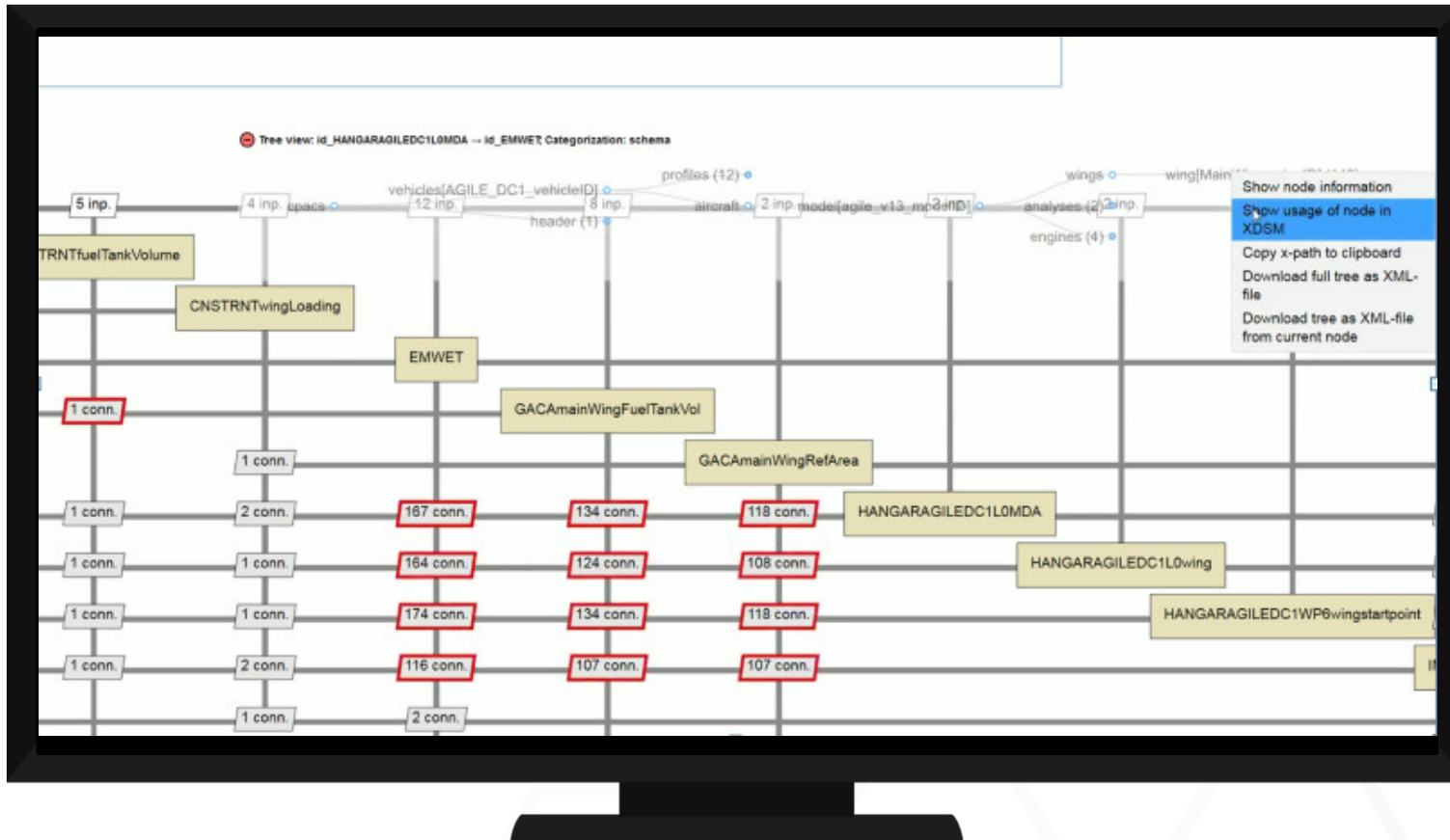
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# Collaborative Inspection

source: b. aigner, i. van gent et al., "Graph-Based Algorithms and Data Driven Documents for Formulation and Visualization of Large MDO Systems", CEAS Aeronautical Journal, 2017



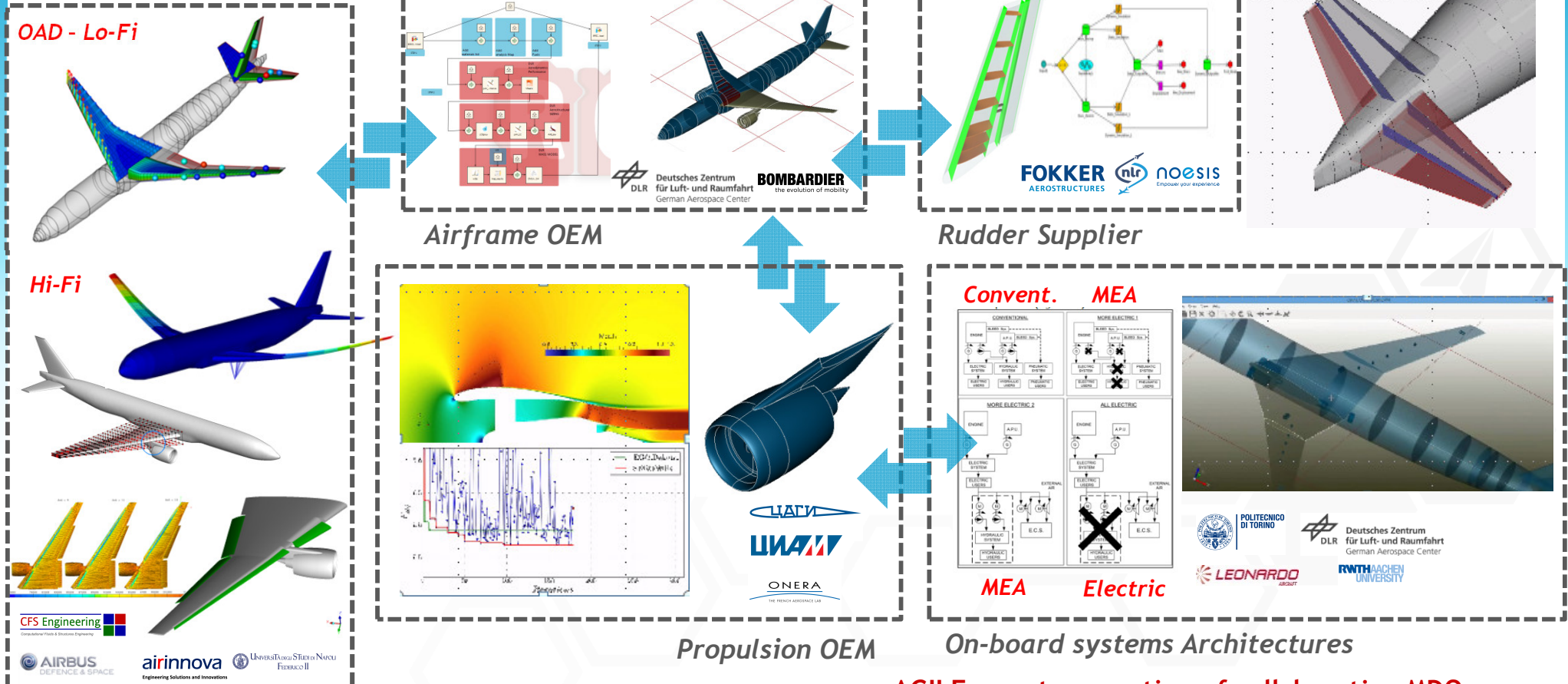
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# AGILE Phase 2 - 1 aircraft, 5 MDO scenarios in 12 months

Multi-Fi Models @ Partners



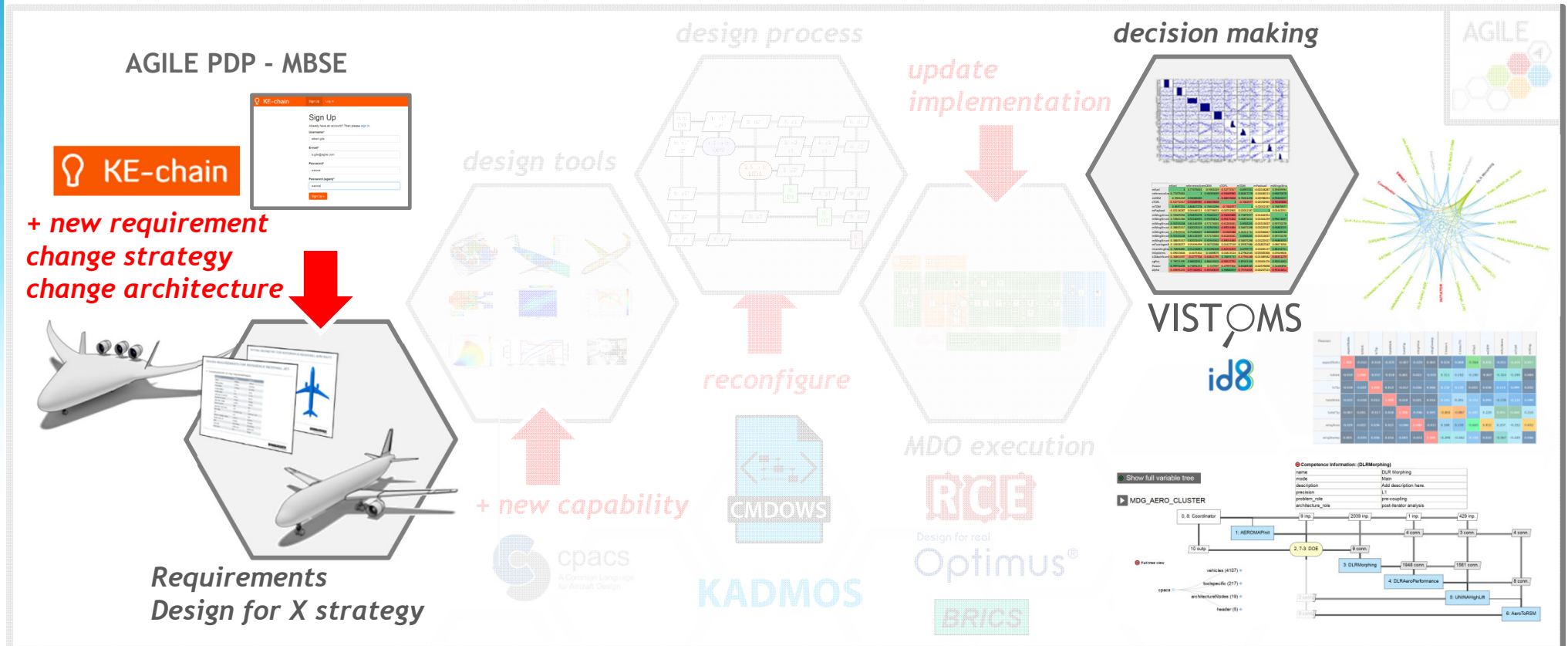
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# AGILE Framework - *Product development*

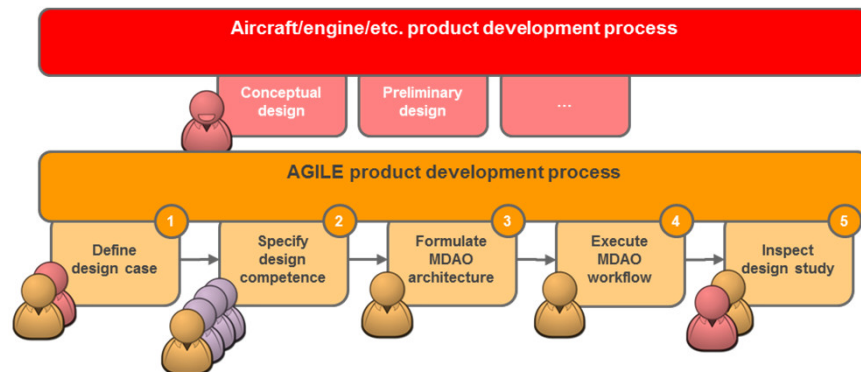
AGILE Framework



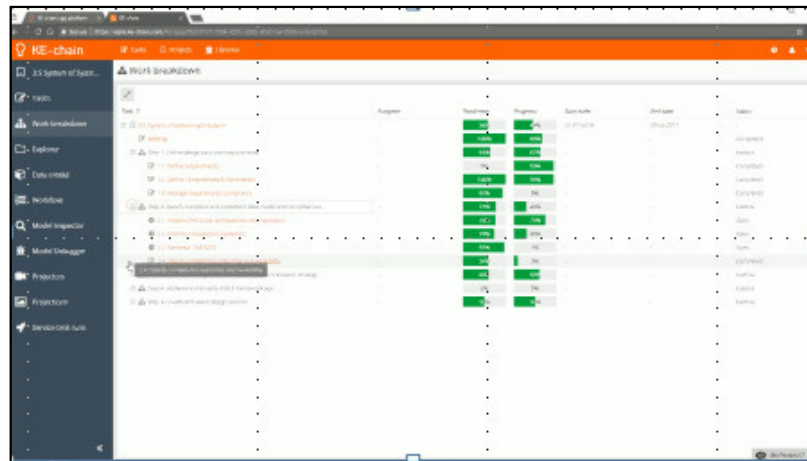
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# AGILE Distributed Development Process



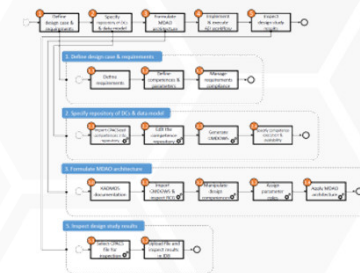
- *Requirements MGMT*
- *Problem Definition*
- *Link to the “executable” world*
- *Collect the info\results*
- *Engineers in the loop*
- *Understanding the process*
- *Traceability of the (detailed) info*



← **TLAR Objectives**

← **Input\output**

← **MDF BLISS**

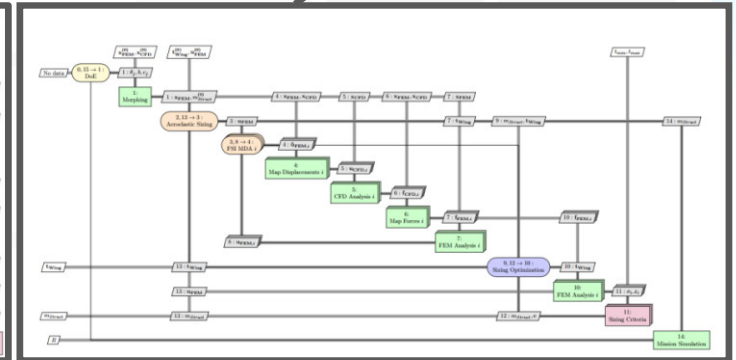
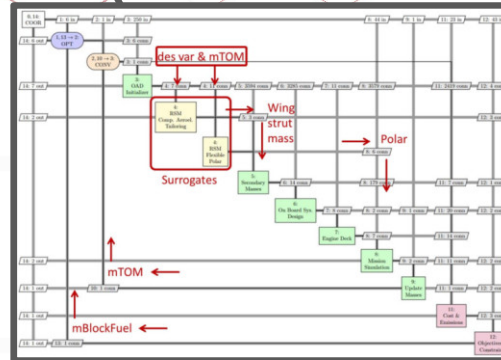
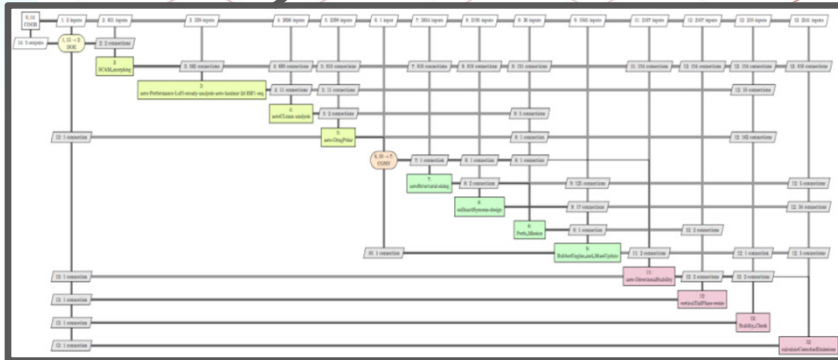
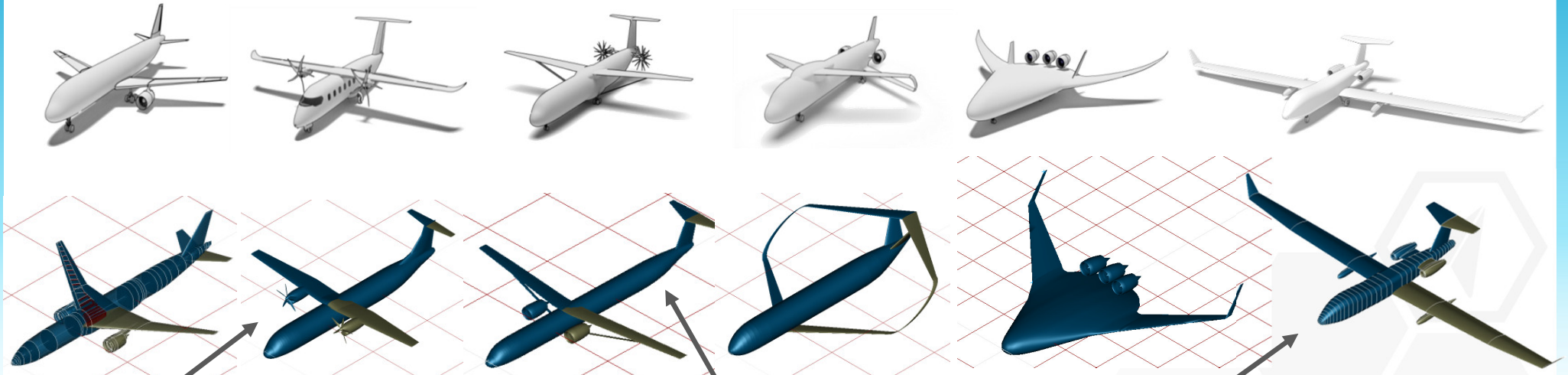


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# AGILE Phase 3 “Ongoing” - *6 aircraft in 15 months*

## AGILE Configurations

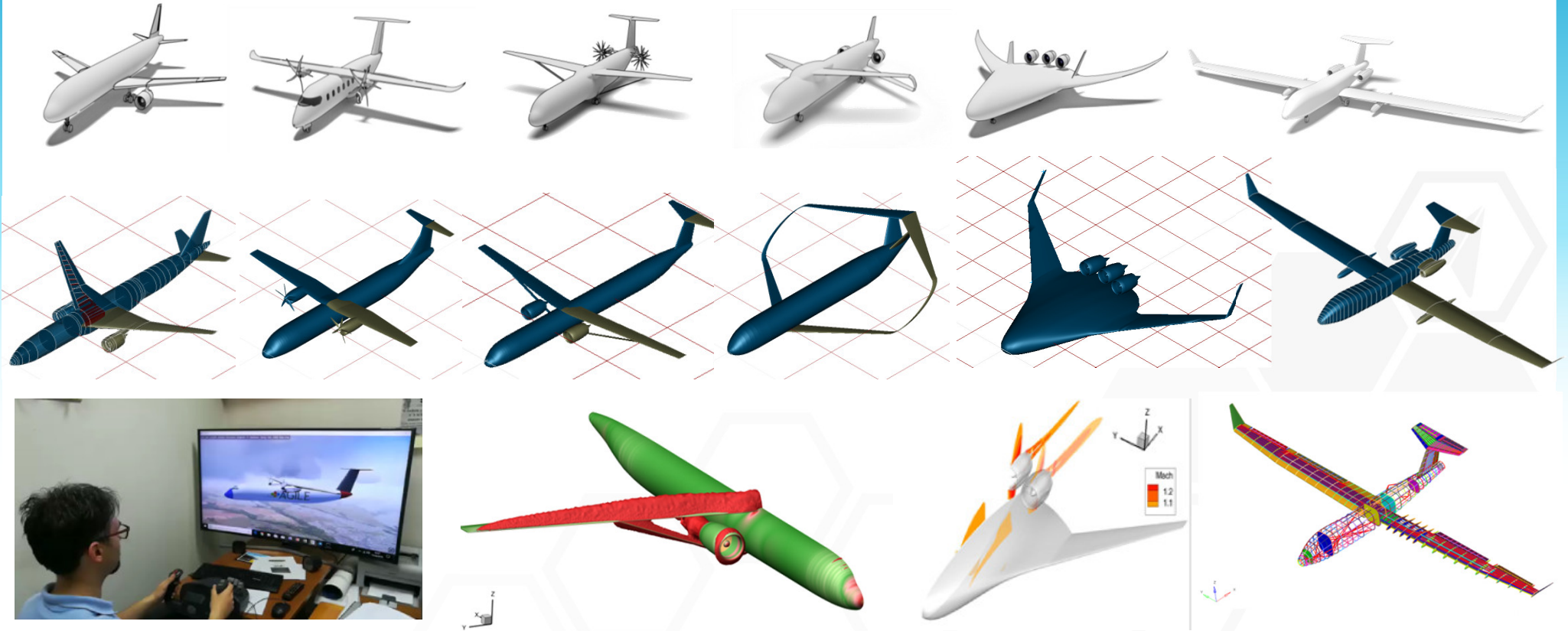


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# AGILE Phase 3 “Ongoing” - *6 aircraft in 15 months*

## AGILE Configurations



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# AGILE Project Outcome

## AGILE Achievements:

- Accelerating the deployment of design and optimization processes
- Large-scale cross-organizational MDO processes of tools and people
- AGILE Framework operational with 19 partners

1

### AGILE Aircraft Database:

- Database of novel configurations for follow-on projects
- 6 novel aircraft configurations accessible (data and models)
- Current aircraft results are **already exploited** in running projects



2

### AGILE Technologies:

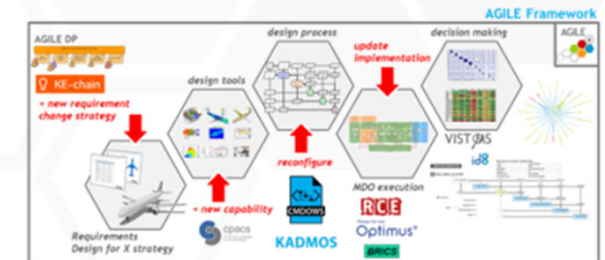
- The AGILE framework released as **open-source**
- Prototypes already exploited in internal and external projects
- AGILE Paradigm a “**blueprint for collaborative MDO**”



## AGILE Academy:

15 International Organizations

NOT in AGILE using the AGILE framework!



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# AGILE ACADEMY



<https://agile-project.eu/agile-academy>

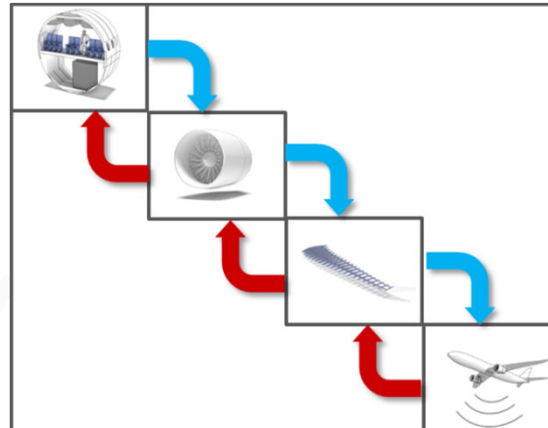
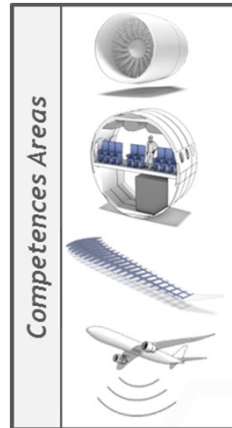
## Objectives of the Initiative:

1. Introduce the “**AGILE Paradigm**” in Education\Research
2. Release the AGILE technologies **outside the Consortium**
3. Enable “**effective**” **Collaboration** among multiple institutions



1) *Distributed Competence*    2) *Collaborative aircraft design*

## 3 Teams



1<sup>st</sup> AGILE Academy Workshop in Hamburg

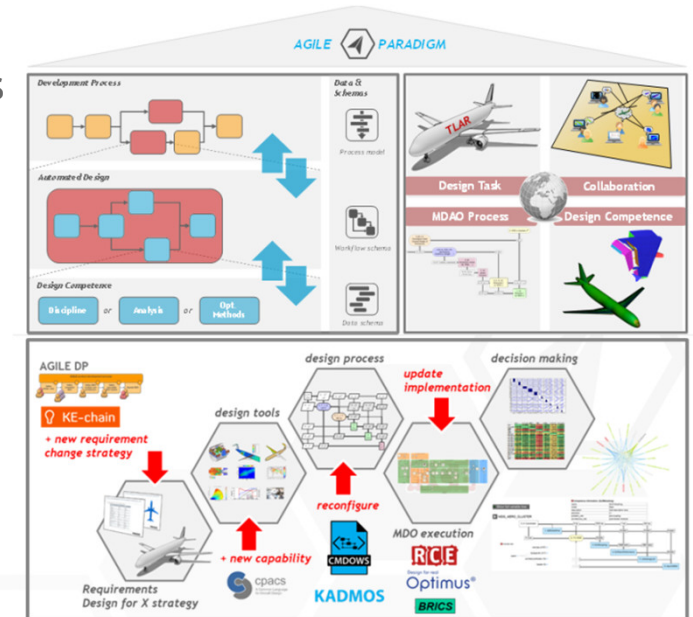


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# Wrap-up

- Challenges for the next generation MDO
  - Enable the setup of large design and optimization processes of tools and people (cross-organizational)
  - Formalization of the PDP and MDO processes
- AGILE Progresses
  - AGILE Paradigm: quick setup of coherent MDO process
  - AGILE Framework operational with 19 partners
  - Year 1: **2 MDO workflows** (scenarios), **conventional**, **manual**
  - Year 2: **16 MDO workflows**, **conventional**, **AGILE Framework**
  - Year 3: **6 MDO workflows**, **un-conventional**, **AGILE Framework**



**AGILE - next generation of collaborative MDO**

# Achievements

- **AGILE special sessions**
- Special MDO session on AGILE
- AGILE presented at the High level Forum 360 Panel with EC representatives on “Aviation Transformation in Europe”
- **AGILE @ Air Shows**
- Flying simulator at the EC stand
- AGILE presented at the workshop “Disruptive configurations”
- **AGILE at ICAS 2018**
- Special MDO sessions on AGILE
- ICAS „*Award for Innovation in Aeronautics*“



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# AGILE Team

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Reinhold Maierl	Airbus
Arthur Rizzi	Airinnova
Tomas Melin	Airinnova
Mengmeng Zhang	Airinnova
Bruno Tranchero	Leonardo
Giovanni Cerino	Leonardo
Giuseppe Piscopo	Leonardo
Luciana Loverde	Leonardo
Roberto Labruto	Leonardo
Nicola Catino	Leonardo
Fassi Kafyeke	Bombardier
Graham Potter	Bombardier
Balaji Periyapatna	Bombardier
Hugo Gagnon	Bombardier
Jasveer Singh	Bombardier
Stephane Dufresne	Bombardier
Aidan Jungo	CFSE
Dominique Charbonnier	CFSE
Jan Vos	CFSE
Aleksander Lanshin	CIAM
Alik Isyanov	CIAM
Artur Mirzoyan	CIAM
Pavel Toktaliev	CIAM

Björn Nagel	DLR
Erwin Moerland	DLR
Francesco Torrigiani	DLR
Jan-Niclas Walther	DLR
Jonas Jepsen	DLR
Kathrin Althaus	DLR
Olaf Brodersen	DLR
Pier Davide Ciampa	DLR
Prajwal Shiva Prakasha	DLR
Stefan Keye	DLR
Xiangyu Gu	DLR
Sascha Zur	DLR
Luc Hootsmans	Fokker
Ton van der Laan	Fokker
David Cooper	GenWorks
Joost Schut	Ke-Works
Bastiaan Beijer	Ke-Works
Stefan van der Elst	Ke-Works
Erik Baalbergen	NLR
Huub Timmermans	NLR
Jos Vankan	NLR
Bert de Wit	NLR
Onno Bartels	NLR
Wim Lammen	NLR
Marco Panzeri	NOESIS Solutions
Riccardo Lombardi	NOESIS Solutions
Roberto d'Ippolito	NOESIS Solutions

Nathalie Bartoli	ONERA
Rémi Lafage	ONERA
Sylvain Dubreuil	ONERA
Thierry Lefebvre	ONERA
Luca Boggero	Polito
Marco Fioriti	Polito
Francesca Tomasella	Politi
Sabrina Corpino	Polito
Benedikt Aigner	RWTH
Eike Stumpf	RWTH
Martin Spieck	Thelsys
Sabine Spieck	Thelsys
Alexander Lysenkov	TsAGI
Andrey Savelyev	TsAGI
Kirill Anisimov	TsAGI
Maria Sakharova	TsAGI
Darwin Rajpal	TUDelft
Gianfranco La Rocca	TUDelft
Imco van Gent	TUDelft
Mark Voskuijl	TUDelft
Roeland de Breuker	TUDelft
Agostino De Marco	Unina
Danilo Ciliberti	Unina
Fabrizio Nicolosi	Unina
Luca Stingo	Unina
Pierluigi Della Vecchia	Unina
Vincenzo Cusati	Unina



**19 Partners**  
**25 Sites**  
**>110 Members**



**>70 Tools**  
**8 Platforms**  
**9 Aircraft**



**>120 papers**  
**~40 thesis**  
**~15 sessions**  
**2 Academy**



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